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Experimental Study on Relation between Micro-structure and Macro-performance of Zeolite-based Humidity Control Building Coating

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Abstract

A new humidity controlling coating with great absorption and desorption is developed by the modification of natural zeolite by microwave assisted ammonium chloride. The surface and the structures of the zeolite are measured by SET. The moisture absorption and desorption rate of coating with natural zeolite is tested and compared with that of the coating with modified zeolite. The results show that compared with natural zeolite, the moisture absorption and desorption capacity of the zeolite samples can enhance27%、15%, which are modified by 3% saturated ammonium chloride and 100w microwave heating 3 minutes.

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Keywords: modification; zeolite; humidity controlling coating;

1. Introduction

Humidity is so important to human health, and living environment, as relative humidity in door， which are too high or too low have adverse effect on our living conditions. [1,2]It has been suggested that interior wall coatings can be used as humidity controlling materials. A humidity control building coating (HCBC) can absorb or release moisture automatically without any power source or mechanical equipment due to its sensitivity to the variations of ambient

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temperature and RH. [3−5]Thus, the use of a HCBC is of great importance to the indoor environment, energy conservation and sustainable development of the ecological environment.

Since the use of a HCBC was initially proposed by a Japanese scholar, it has received considerable interest at home and abroad. Many kinds of HCBCs were developed, including the water-based coatings, latex coatings, and nanocomposite coatings. [6]The determination and mechanism of properties of HCBCs were discussed widely. For instance, studies on the criteria for estimating materials' indoor humidity control capacities were conducted by Morooka et al. Xiao and Qian investigated the humidity-dependent capillary force. [7]What is more, people did many researches on developing new humidity control coatings with superior performance of humidity control, such as composite humidity control coatings, potassium acetate/polyacrylamide composites and control composite material based on CMC. [8]However, humidity control composite coatings with excellent moisture capacity, well-distributed pore and fast response to humidity changes of ambient environment are under study.

The research studies described above experimentally characterized the HCBC on the macroscopic scale, HCBC primarily examining the original material selection, the optimal treatment and the best mixed portions of raw materials, as well as the humidity control performance measurement of the HCC. As a typical porous media, the micro-structure of HCBC (e.g., porosity, pore size distribution and pores morphology) might have an influence on the humidity control performance of the HCBC. To the best of our knowledge, there are only a small number of reports describing research in this area.

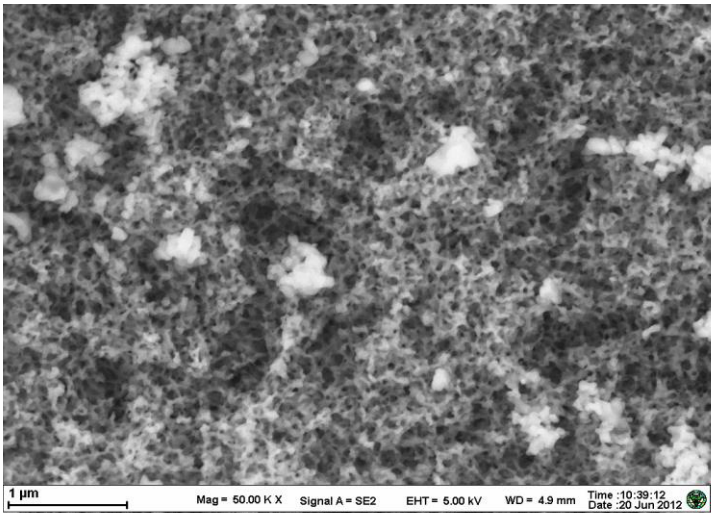
2. Experiment

2.1 Materials

Acrylic acid, butyl acrylate, methyl methacrylate, hydroxyl methacrylate, acrylamide, zeolite， sodium lauryl sulfate, Tween-20, polyoxyethylene octylphenol ether were obtained from commercial sources.

2.2 pretreatment of zeolite

Zeolite is the main humidity control component of HCBC, Fig 1 shows the SEM micrographs of untreated and modified zeolite. The test sample of zeolite was modified by microwave and ammonium chloride. Compared the pores distribution of untreated and modified zeolite， modification of zeolite change the micro-morphology of surface, which appears regular, homogeneous distribution and many smaller pores. Obviously, the main aim of these modifications is to change the micro pore structure of zeolite, which can improve the humidity control performance of HCBC.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Signal A = SE2
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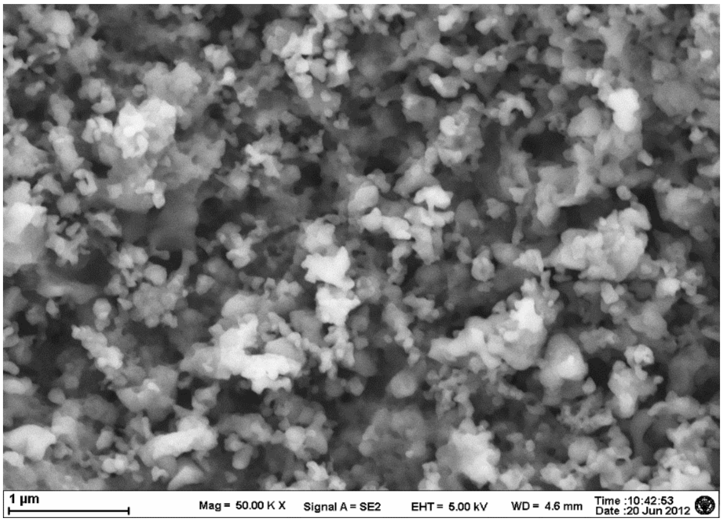
(a)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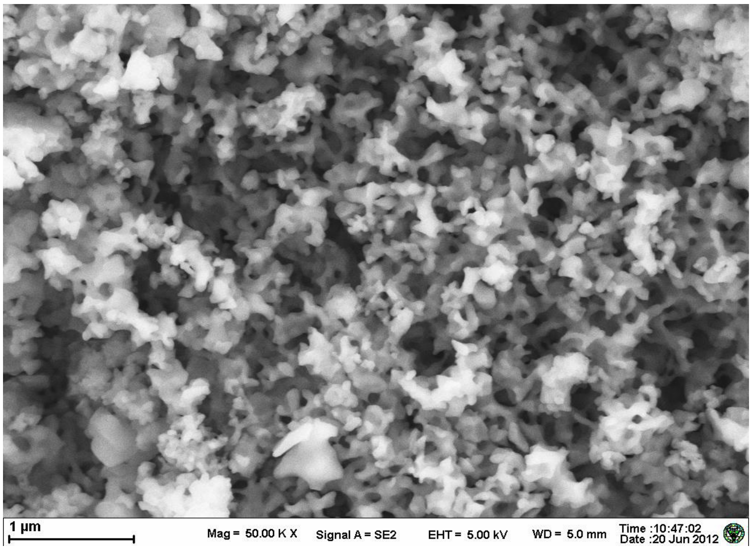
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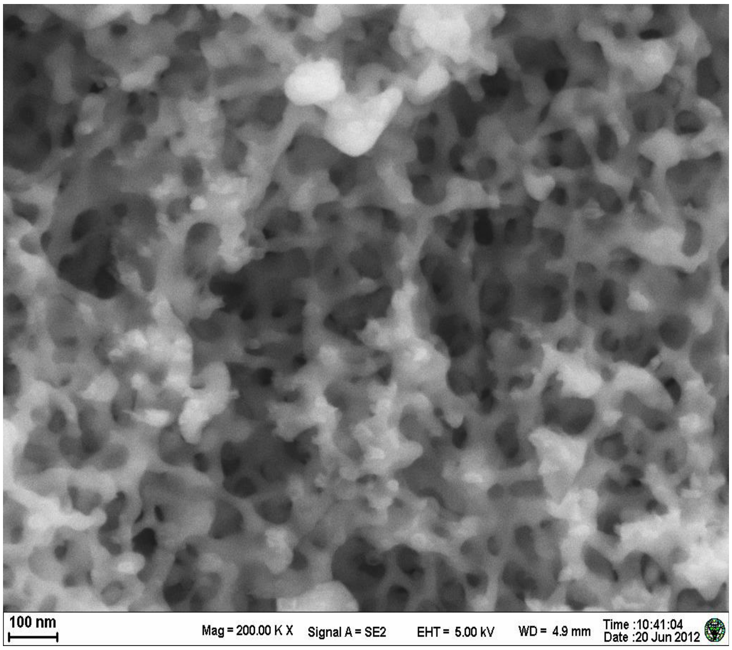
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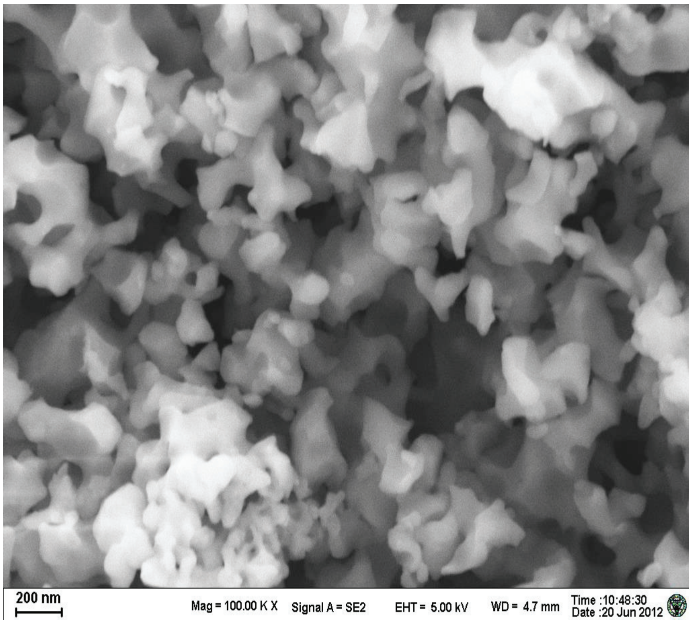

(e)

Fig 1. SEM images of the zeolite: (a) the natural zeolite; (b) (e) the natural zeolite after first modifying;

(c) (f) the natural zeolite after twice modifying

2.3 Experimental apparatus

The schematic diagram of the experimental apparatus used in the test is shown in Fig.2.The apparatus primarily consisted of following systems: blocks weighting, data acquisition system, test chamber system. The test chamber system consisted of a sealed plastic box, testing coats, stirring fan, clapboard, riser vent and saturated saline solution. The stirring fan was applied to promote the diffusion of moisture in the chamber therefore providing uniform distributions of temperature and RH in the chamber. Saturated saline solution at different temperatures was used to maintain high RH/ low RH artificial environments, as indicated in Tab.1.

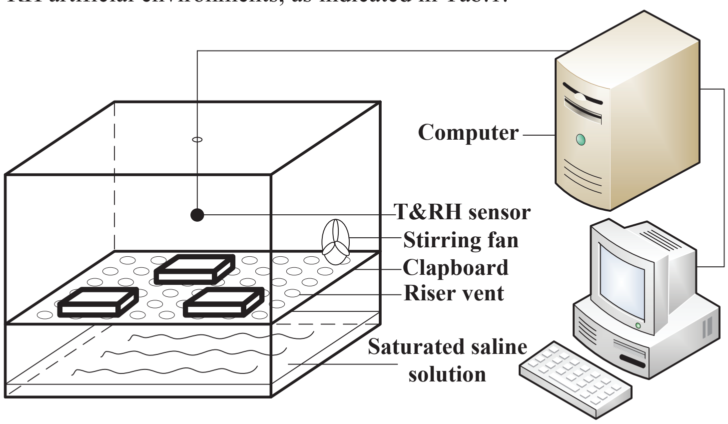

Fig. 2 Schematic diagram of the experimental apparatus

The data acquisition system was comprised of a T&RH sensor, the data acquisition equipment and a recording computer. The T&RH sensor was positioned above the blocks to monitor the temperature and humidity of chamber. All the temperature and humidity data were recorded using a data acquisition system, which was connected to the recording computer. The weighting system for the blocks was a high precision electronic balance FA2004N with an accuracy of 0.0001g.

The experimental setup was used to maintain the experimental temperature and RH within certain rang and records the variations of the adsorption and desorption contents of the HCBCs at certain times.

Table 1. RH of saturated saline solution at 20 ℃

Name	Molecular formula	RH /%
magnesium chloride	MgCl2	33.07±0.18
potassium chloride	KCl	85.11±0.29

2.4 Testing protocol of the HCBCs

The dehumidifying and humidity increasing properties of the HCBCs were measured in moist and dry environments .First; the HCBCs were brushed onto glass plates, and dried. The functions of these coatings were measured in an artificial climate box (9L) as follows:

(a) Dehumidifying properties: The dry-coated sheets of HCBCs were placed in the box, which was put in the artificial climate box with an relative humidity more than 85%.The curve of RH vs. time was recorded.

(b) Humidity increasing properties: The humidity controlling sheets of HCBCs were placed in the box, which was put in the artificial climate box with a relative humidity less than 30%. The curve of RH vs. time was recorded.

3. Discussions

The experiments mainly study the humidity control performance of zeolite and HCBC, so the temperature environments are settled as 20℃.

3.1 Effect of the ambient RH on the humidity control properties

Fig. 3、4 presented the effect of ambient RH on the humidity control properties of HCBCs. The adsorption and dehumidification speed curves of these three different samples were discussed. The letter F stand for a coating with raw zeolite samples .The letters F and N stand for a coating with the zeolite samples, which are modified by 3% saturated ammonium chloride.The letters F , N and W stand for a coating with the zeolite samples, which are modified by 3% saturated ammonium chloride and 100w microwave heating 3 minutes. As shown in Fig. 3、4, the adsorption and the dehumidification speed curves in the first 10 hours exhibit sharp slopes due to the high concentration gradient of the moisture between the chamber environment and within the testing samples. Compared with natural zeolite, the moisture absorption and desorption capacity of the zeolite samples can enhance27%、15%, which are modified by 3% saturated ammonium chloride and 100w microwave heating 3 minutes.

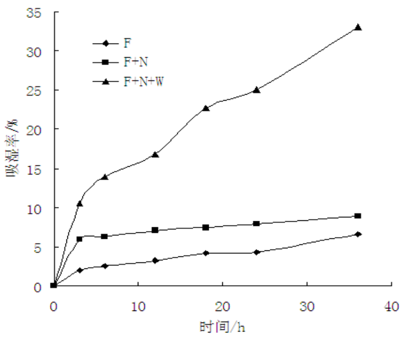

Fig. 3 Humidity-controlling capability at 80%RH

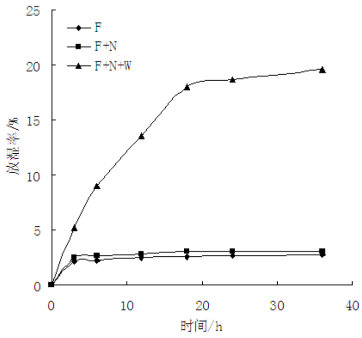

Fig. 4 Humidity-controlling capability at 30%RH

4. Conclusions

The experiments were performed investigating the hydrothermal performance of HCBCs. The effects of porosity, pore structure on the humidity control performance of HCBCs were studied.

The results indicated that the adsorption and desorption performance of a HCBC is strongly affected by the porosity and pore structure. compared with natural zeolite, the moisture absorption and desorption capacity of the zeolite samples can enhance27%、15%, which are modified by 3% saturated ammonium chloride and 100w microwave heating 3 minutes. A new humidity controlling coating with great absorption and desorption is developed by the modification of natural zeolite by microwave assisted ammonium chloride.

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